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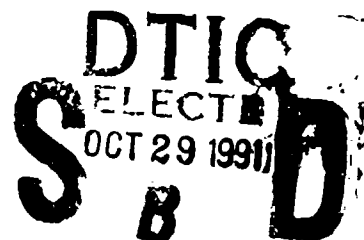


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Measuring Training Productivity in Navy Schools

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13. ABSTRACT (Maximum 200 words) The training productivity of Navy schools depends on levels of student attrition, training time, and student achievement in terms of test scores. Navy training administrators need a method for assessing training productivity that accounts for changes in these three criteria. Mathematical formulas for combining values of these criteria into a single overall index of achieved training productivity were developed. These formulas were applied to demonstrate how training productivity may be assessed and compared for different schools or time periods. It was concluded that this index of achieved productivity is an effective device for monitoring the training productivity of Navy technical schools.			
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FOREWORD

This advanced development effort was conducted under program element 0603720N (Education and Training), project work unit R1772, task ET003 (Skills Enhancement Program). It was sponsored by the Chief of Naval Operations. The objectives of the work unit were to develop guidelines for identifying the Navy school requirements for enhanced student preparation and training support, and methods for addressing these requirements.

The objective of the present effort was to establish an index of training productivity for use in evaluating Navy training programs based on currently available criteria.

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SUMMARY

Background

Large training organizations such as the U.S. Navy need to maintain a constant watch over the productivity of their training programs. Training productivity reflects a school's training outputs in terms of the quantity of graduates and the level to which they are trained, as well as the training inputs needed to maintain training effectiveness. While a variety of criteria contribute to training productivity, no method is presently available for combining these criteria into a single overall productivity index.

Objective

The objective of this effort was to develop an index of productivity that combines major productivity criteria, now available from Navy data bases. These criteria include graduation/attrition rates, setback rates, and course test scores.

Approach

Formulas for combining graduation rates, setback rates, and test scores into a single index of productivity were developed and applied to recent training data from four Navy ratings. Using these formulas, yearly values of achieved productivity were computed for each rating for each of several years of instruction.

Results

Resulting values of achieved productivity were found to reflect combined changes in the values of individual criteria in a reasonable and logical manner.

Conclusion

The index of achieved productivity is an effective device for monitoring the training productivity of Navy technical schools.

Recommendation

An index of achieved productivity should be maintained by an appropriate Navy training activity and reported to training administrators to assist them in monitoring the productivity of technical schools.

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INTRODUCTION

Background

Large training organizations such as the U.S. Navy need to maintain a constant watch over the productivity of their training programs. Training productivity reflects the quantity and quality of a school's training output in terms of the number of graduates and the level to which they are trained. Training productivity also reflects the resources required to achieve outputs such as time and costs. Training productivity can be increased by raising outputs or decreasing inputs.

Different indices of training productivity are monitored by individual school commands and reviewed by higher level Navy training organizations responsible for the allocation of training resources. Training productivity is a major concern to such organizations since decreases in training productivity can inflate training costs and fail to meet fleet manpower needs for qualified school graduates who can perform effectively on the job. Schools with low productivity may require more resources or longer course lengths in order to meet their training requirements.

Maintaining training productivity is not the whole story. The advent of the Total Quality Leadership program into the Navy has emphasized the need for measures of productivity that can be used to improve the quality of products. In Navy training, the product consists of school graduates and the quality of that product depends on the quality of the training provided. The Navy is constantly revising tests and course work, implementing motivational techniques, and introducing new training methods and technologies to improve training.

While the need to monitor Navy training productivity may be readily recognized, the criteria that should be used in determining productivity are less obvious. Historically, the criteria most frequently used by Navy administrators in determining or comparing the training productivity of Navy schools have been student attrition or graduation rates and setback rates. One reason for this is the ready availability of such data. Numbers of students, attrites, graduates, and setbacks in Navy schools have been recorded and maintained in Navy data bases for over a decade.

However, attrition/graduation rates and setback rates only provide part of the productivity picture. Attrition/graduation rates are indications of training quantity. Setback rates are indications of training resource requirements (in terms of training time). Neither of these criteria provide an indication of the quality of training outputs. An indication of training quality is readily available, however, in the form of course test scores. Course test scores may be considered as indexes of training quality in that they indicate the proportion of the course work that the students have mastered. Presumably, students who have mastered course objectives will perform better on the job. If this is not the case, the existing training objectives are inappropriate and should be revised.

Until recent times, records of course test scores were only available to the schools that recorded them since they were not maintained in Navy data bases. However, such records can now be obtained for any Navy school that is supported by the Instructional Support System (ISS). Established in 1984, ISS is maintained by the Navy Education and Training Program Management Support Activity (NETPMSA).

As an index of productivity, course test scores are useful in their own right. Unlike attrition and setback rates, which may be increased or decreased by school administrators without regard for how well students are performing, changes in course test scores directly reflect student achievement.

Because training productivity depends on multiple criteria, it is important to consider all relevant criteria in conducting course evaluations. Otherwise, one criterion may be enhanced at the expense of the others. In such a case, training effectiveness may appear to be improved when in reality one training problem has merely been substituted for another. An excellent example of such a situation is depicted in Table 1.

Table 1
Changes in Radioman (RM) Productivity Data

Year	Setback Rate	Graduation Rate	Average Test Score
1986	25%	84%	90%
1987	8%	76%	90%
1988	0%	77%	92%
1989	24%	85%	93%

Data in Table 1 indicate that, from 1986 to 1987, setbacks were reduced from 25 to 8 percent, a major improvement. During the same period, however, the graduation rate decreased from 84 to 76 percent. Later, the low number of graduates was, apparently, a cause for concern and, from 1988 to 1989, the graduation rate was raised from 77 to 85 percent, another major improvement. At the same time, however, setbacks increased from 0 to 24 percent.

These data indicate that neither lowering the setback rates in 1987 nor raising the graduation rates in 1989 produced real gains in training productivity. In fact, during both of these periods, test scores remained fairly stable. What actually occurred was that one index was improved at the expense of another.

In this example, course test scores did not vary as a function of graduation or setback rates. Under other conditions, however, we might expect test scores to interact with other productivity criteria. For example, we would expect that raising student achievement on tests would lead to higher graduation rates since, with higher scores, fewer students would fail course sections. Conversely, increases in academic attrition might actually raise test score averages. This could occur if the lower scoring students were eliminated early in the course and did not participate in later course sections.

Since graduation rates, test scores, and training time can interact and vary at the same time, it is often difficult to determine what such changes mean. Are the training outcomes positive,

negative, or neutral? Have we gained or lost productivity? It would be useful in such circumstances to be able to combine these criteria into a single overall productivity index.

Objective

The objective of this effort was to develop an index of productivity that combines major productivity criteria, now available from Navy data bases. These criteria include graduation/attrition rates, setback rates, and course test scores.

APPROACH

Establishing Productivity Formulas

Overall Productivity

The first consideration in the development of productivity formulas was how to combine graduation rates, setback rates, and test scores into a single index of overall productivity. This goal was achieved through the use of the formula:

$$P_o = (G \times S)/(T_c + T_s),$$

where P_o is overall productivity, G is the graduation rate (the percentage of students who graduate), S is the average test score for the course (the percentage of correct answers), T_c is the course length (in days of instruction), and T_s is the number of additional days of instruction due to setbacks.

This combined index P_o has several advantages. First of all, an increase in one factor at the expense of another will limit overall gains. For example, if more students are graduated without increasing student test scores or providing more training time, average test scores should fall since the lower scoring students are being retained. In such a case, the increase in P_o due to the higher percentage of graduates will be compensated for by a decrease in P_o caused by lower test scores. In a similar manner, attempting to increase the number of graduates by allowing more setbacks to occur would have opposing effects on P_o . The increase in the number of graduates would raise P_o but the increase in total training time from the increased setbacks would lower it. A second advantage of the index P_o is that its extreme values are appropriate in a mathematical sense. For example, as the graduation rate (G) and the average course test score (S) each approach 100 percent, the value $G \times S$ approaches 100 percent. If either G or S approach 0 percent, then $G \times S$ approaches 0 percent. These are reasonable outcomes since the value of training is only maximized if both training quantity and quality are maximized, but training is worthless, either if no one graduates or nothing is learned.

Still another advantage of P_o is that it translates setbacks into training time (T_s). T_s added to T_c (course length) represents total training time for the course. This, in turn, allows graduation rates and test scores to be examined in relation to the total amount of training time provided to students.

To determine T_s for a given course, three values are needed: the number of students, the number of setbacks, and the average duration in days of setback periods. Values for all three can be readily obtained from ISS. ISS data include setback periods for each student. These can be averaged to determine the average length of setback per student (in days). T_s can then be calculated by multiplying the average setback length by the number of setbacks and dividing by the total number of students.

$$T_s = \frac{\text{average setback length in days} \times \text{No. of setbacks}}{\text{total No. of students}}$$

Table 2 presents examples of calculated values of T_s and the data on which these calculations were based.

Table 2

Setback Data for the Radioman (RM) "A" School

Year	No. of Students	No. of Setbacks	Setback Length	Setback Time Per Student (T_s)
1986	2,956	700	8 days	1.9 days
1987	2,695	223	9 days	0.7 days
1988	2,567	0	0 days	0.0 days
1989	2,430	574	15 days	3.5 days

T_s is a useful index, in its own right, for comparing trade-offs between setback time and course length. Generally speaking, if the length of a course is increased without changing the curriculum, we would expect setback time to decrease since, with more time to study, students should achieve higher test scores and require less setback time. This, in turn, raises the possibility that increases in course length could actually decrease overall training time by reducing the number of setbacks. As a hypothetical example, suppose that, at a school, setbacks are found to add an average of 10 days of training time per student. Further, suppose that setbacks could be eliminated by adding 7 days to the length of the course. In such a case, the addition of 7 days in course length would eliminate 10 days of setback time and actually reduce total training time by 3 days.

Having calculated amounts of setback time (T_s) (as displayed in Table 2), we can use our formula to obtain values of P_o for the RM "A" school. Graduation rates (G) and average test scores (S) can be obtained from Table 1. T_c (the normal length of the RM course) is 65 days. Inserting these values into our productivity formula produces the following values of P_o for the period from 1986 through 1989:

$$1986: P_o = (84\% \times 90\%) / (65 + 1.9) \text{ days} = 1.13\% \text{ per day}$$

$$1987: P_o = (76\% \times 90\%) / (65 + .7) \text{ days} = 1.04\% \text{ per day}$$

$$1988: P_o = (77\% \times 92\%) / (65 + .0) \text{ days} = 1.08\% \text{ per day}$$

$$1989: P_o = (85\% \times 93\%) / (65 + 3.5) \text{ days} = 1.15\% \text{ per day.}$$

These values of P_o combine the effects of graduation rates, test scores, and setback times. In their present form, however, they are of limited use. They can be used to compare productivity achieved during different time periods, but they provide little insight in terms of the significance of the levels achieved. Is the 1989 RM "A" school productivity level of 1.15 percent high? Is the 1987 level of 1.04 percent low? It's difficult to say. A more useful index of productivity can be obtained by expressing overall productivity levels as percentages of potential overall productivity.

Potential Overall Productivity

Potential overall productivity (P_p) is defined here as the highest level of productivity that can be obtained with existing course lengths. The highest possible level of productivity occurs when the graduation rate (G) is 100 percent, the average course test score (S) is 100 percent, and the rate of setbacks (T_s) equals zero so that total training time equals T_c , the length of the course.

P_p can be calculated with the same formula used to calculate overall productivity (P_o), by substituting 100 percent for G and S , and 0 days for T_s :

$$\begin{aligned} P_p &= (G \times S) / (T_c + T_s) \\ &= (100\% \times 100\%) / (T_c + 0) = 100\% / T_c. \end{aligned}$$

Since T_c (normal course length) for the RM "A" school is 65 days, the potential overall productivity of the RM "A" school is:

$$P_p = 100\% / 65 \text{ days} = 1.54\% \text{ per day.}$$

Achieved Productivity

Having developed an index of potential productivity (P_p), it now becomes possible to consider overall productivity (P_o) (the productivity achieved) as a percentage of potential productivity. The achieved percentage of potential productivity is designated here as P_a and is expressed as:

$$P_a = P_o / P_p.$$

That is, achieved productivity equals overall productivity divided by potential overall productivity.

Applying Productivity Formulas

To demonstrate the utility of an index of achieved productivity, these productivity formulas were applied to obtain values of achieved productivity based on recent student performance in several Navy schools.

RESULTS

To determine whether the proposed index of achieved productivity provides a meaningful summary of available productivity data, we obtained values of achieved productivity based on

recent student performance in several Navy technical schools. Analyses were performed for the RM "A" school students and for "A" school students from several other Navy ratings that are monitored by ISS and have experienced major changes in graduation rates, test scores, or setback rates in recent years. These include Quartermaster (QM), Aviation Control Technician (AQ), and Avionics Technician (AT) students. Values of achieved productivity were obtained only for the years in which major changes occurred in total training times ($T_c + T_s$), graduation rates (G), or average test scores (S).

Obtained values of achieved productivity are presented in Table 3 with the data on which they are based. Data in Table 3 for the RM students indicate moderately high levels of productivity achievement with the highest level in 1989. These levels appear reasonable considering that test scores and graduation rates were also moderately high during these periods. Both test scores and graduation rates peaked in 1989, resulting in the highest productivity level for the four-year period. However, productivity for 1989 was less than it might have been due to the increase in the number of setback days that occurred between 1988 and 1989 (see Table 2).

Data in Table 3 indicate a sizeable increase in achieved productivity for QM students between 1986 and 1987. The gain in productivity appears reasonable since graduation rates and course test scores both increased while training time decreased. Some of these gains in productivity were lost in 1989, despite a slight increase in test scores. These test score increases were more than offset by a decreased graduation rate and longer training time.

Data in Table 3 indicate large drops in achieved productivity for both AQ and AT students between 1988 and 1989. The magnitude of the losses appears reasonable in that all three productivity criteria combined to lower productivity. Graduation rates and test scores decreased while total training time increased during these periods. AQ and AT students show similar productivity patterns since students in both ratings train together at the same "A" school.

DISCUSSION

We have demonstrated how a single index can provide a meaningful assessment of achieved productivity using available productivity data. Consideration will now be given to the use of this achieved productivity index, its applications, and its limitations.

The primary advantage of this index is that it accounts for interactions among productivity criteria. When simultaneous changes occur in different productivity criteria, this index indicates if the combined effect of the changes represents an actual improvement in training effectiveness or if we have merely sacrificed one productivity criterion for another.

This index could be particularly useful to those responsible for monitoring the overall effectiveness of Navy technical training. The index can be used to compare the productivity of different Navy schools. This is possible despite differences in the difficulty of their training content or course length, because all schools are compared in terms of their potential achievement. Such comparisons could be used as a basis for assigning schools priorities for training assistance.

Table 3

"A" School Productivity Data for Selected Ratings

Year	Total Training Time ($T_c + T_s$) ^a	Grad. Rate	Average Score	Achieved Productivity
Radioman Students				
1986	66.9 days	84%	90%	73%
1987	65.7 days	76%	90%	68%
1988	65.0 days	77%	92%	71%
1989	68.5 days	85%	93%	75%
Quartermaster Students				
1986	21.5 days	89%	87%	76%
1987	21.1 days	94%	89%	83%
1988	21.0 days	93%	90%	84%
1989	21.2 days	90%	91%	81%
Aviation Control Technician Students				
1988	110.0 days	86%	89%	77%
1989	112.0 days	76%	84%	63%
Avionics Technician Students				
1988	110.1 days	90%	90%	81%
1989	112.5 days	82%	86%	69%

^a T_c = Course length.

T_s = Setback time.

Yearly summaries of achieved productivity could be used to identify training problems that need to be addressed. When the achieved productivity of any Navy school slips below prescribed levels, corrective measures can be taken. When a school's achieved productivity approaches the higher levels of potential achievement, excessive training time or resources may be expended. Under such conditions, it may be desirable to shorten course lengths or reduce training resources. When efforts are made to improve training, the same index can provide a basis for assessing the effectiveness of the improvements. Because of the comprehensive orientation of the index, it will be clear whether training effectiveness has actually improved or whether one productivity criterion has been sacrificed for another.

Several considerations should be kept in mind in applying the index. It is probably only meaningful to make productivity comparisons over relatively long time periods. Factors that affect training effectiveness, such as student ability, instructor experience, student/instructor ratios, and classroom habitability, can vary considerably from month to month. Over longer time periods, such variations tend to average out. It is important, then, to maintain productivity records for Navy schools over time so that an established baseline of data is available before schools are compared

or new training methods are evaluated. By the same token, sufficient time should be taken in monitoring productivity under a revised method of instruction so that temporary effects can be ameliorated and training can occur under a range of conditions large enough to provide stable data.

It may be desirable to assign weights to component criteria. While no weights were assigned to criteria in the present study, Navy administrators may wish to emphasize some criteria over others. They might, for example, consider graduation rates more important than test scores or training time. More or less emphasis can easily be placed on any component criteria by assigning the variable a weight; that is, a multiplier to increase or decrease the contribution of the variable to the overall productivity ratio.

Another consideration in determining achieved productivity (P_a) is the accuracy of the recorded data. Accuracy of data is a concern regardless of the productivity criteria that are used. However, data accuracy is a more important problem when several different types of data are combined. For example, if 5 percent of the data entries are missing for each of three criteria, as many as 15 percent of the entries could be missing at least one of the three types of data. Such considerations emphasize the need to ensure that complete and accurate records are maintained.

Still another consideration relates to ensuring the equivalency of test scores used in obtaining values of achieved productivity. While test scores are independent of administrative decisions to raise or lower passing criteria, they are not immune to changes or modifications to course tests. Changes to course tests should be recorded and records of the changes maintained so that investigators will know if test data from different time periods can be compared. Also, different versions of tests are sometimes given to students. Therefore, for comparisons of productivity to be valid, the different test versions used in the comparisons must be equated in terms of content and level of difficulty.

The index of achieved productivity discussed in this paper does not address training costs. Training costs are a major training resource and, therefore, relevant to a determination of training productivity. However, methods for determining the costs of military training are complex and go beyond the considerations of this paper. Total training time, herein, can be translated into training costs when a method of determining costs per day of instruction has been established. With such cost data, the productivity formulas can be expressed in terms of costs rather than days of training.

Finally, the proposed index of achieved productivity should be viewed as a supplement rather than a replacement for the criteria of which it is composed. Criteria such as graduation rates, test scores, and setback times can provide clues to why the overall index may be rising or falling. Also, some decisions may rely only on a single index. For example, for a given rating, a fall in graduation rate beyond a certain point may be considered unacceptable, even if the overall productivity ratio is maintained.

CONCLUSION

In the past, Navy training administrators have sometimes attempted to improve a single aspect of training productivity such as attrition/graduation rates or setback rates without considering the overall effects on training productivity. Such focusing can produce cyclical changes in training emphasis without improving training effectiveness. A more comprehensive approach to training

improvement is needed that considers all available productivity criteria simultaneously. Currently available productivity criteria include attrition/graduation rates, setback rates, and test performance data. We have proposed the use of an overall index of achieved productivity that is sensitive to the effects of all of these criteria. We have presented formulas for combining these criteria into a single productivity index. We have demonstrated how the effects of simultaneous variations in different productivity criteria can be interpreted through the use of such an index. Finally, we have discussed the applications and limitations of the index.

The index of achieved productivity, presented in this report, is an effective device for determining overall productivity levels of Navy technical training schools.

RECOMMENDATION

An index of achieved productivity should be maintained by an appropriate Navy training activity, and reported to training administrators to assist them in assessing the overall productivity of technical schools.

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